

## SUMMARY OF FINDINGS OF FIRST INTERNATIONAL SKID PREVENTION CONFERENCE

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The friction created between a tire and a road surface is essential to the acceleration, steering, and stopping of a vehicle. Indeed, none of these are possible without friction. Yet surprisingly little attention has been given to the nature of these frictional forces until recently. Although the major causes of the lack of adequate traction were recognized 25 years ago, it was not until the last five years that widespread concern over the problem has been noted. The impending construction of the Interstate System has incited further concern over the problem, for on this system the traffic volumes will be heavily concentrated and speeds will be higher and it is essential that all of the contributory facets of the problem be evaluated.

An example might be cited to point out the extent to which slippery conditions might prevail. Assume that during wet weather a vehicle is traveling 50 mph, and for some reason—child, dog, vehicle up ahead—the driver jams on the brake pedal. Under one set of conditions he may travel 120', under another 460' if the vehicle stays on the road. The example above, a locked wheel panic stop, is only one type of skidding problem; others include loss of vehicle control because of the spinning of back wheels during acceleration, and skidding of wheels when rounding a corner. Dry pavements present no special problems of this type, it is only when they're wet that some become slippery.

One important factor that has hindered progress is that the problem cuts across several major fields, i.e., automobile, brake, and tire manufacturers, highway construction, and human engineering. As a result there has been a great deal of independent activity within each field but quite often the others have been unaware of it. Since the problem involved all of the above mentioned fields, it was apparent that the greatest progress could be made by a joint attack on the problem. If each of the industries could orient themselves to the central problem, that of reducing accidents to which skidding is a contributing factor, then the role of each in working towards a solution would be clear. This then was the reasoning that led to the First International Skid Prevention Conference.

*It is my purpose here to give a personal appraisal of the Conference from the highway engineers' viewpoint.* I will not attempt to survey the entire Conference, but hope to give an interpretation of what the Conference will mean to the highway engineer. Specifically, I hope to point out what the other fields are doing to combat skidding accidents and finally what the role of the highway engineer is in the overall problem.

First, in the interest of completeness a few words of background will be given.

The Conference, held at the University of Virginia in September 1958, was planned by representatives of the various organizations concerned with the problem; 17 agencies were represented on the Steering Committee. It was attended by about 200 engineers from this country and abroad, and approximately 30% of the papers were authored by Europeans. A proceedings is being published and will be available in the summer of 1959. The review of the Conference follows and has been sub-divided in six major portions: (1) vehicle, (2) brake, (3) tire, (4) highway, (5) measurements, and (6) human engineering.

## THE VEHICLE

The automotive industry is greatly influenced by popular appeal as are other strongly competitive producers of consumer products and, as is well known, popular appeal includes many intangibles, some of which are not in the best interest of safety. However, if any group is to blame for this condition it is we, the consumer. If the consumer desired safety features and would let the presence or absence of these features influence his choice of an automobile, then the manufacturer would hasten to supply them. Actually the automotive industry is greatly interested in safety; it is aware of the hazards involved in skidding and is actively seeking improvements. But the important point here is that these types of industries are not governed by engineering factors and any long range prediction about future designs must take into account that consumer preference is whimsical.

Some of the aspects of automotive design that bear on skidding and skidding accidents include the design of the vehicle and characteristics of the engine. For instance, the lower center of gravity and the wider wheel spacing laterally of modern vehicles give a considerable advantage in turning movements over the vehicles of a few years ago. Today's vehicles are able to traverse safely many curves at speeds that would have caused an accident even 15 years ago.

Another factor that must be considered is the influence that increased power will have on the road surface. There can be little doubt that increased engine power will result in a greater polishing of the aggregate than did the relatively low powered engines of ten years ago. This is borne out by the wear rates of tires; in recent years the rear tires are showing the greatest wear rates as contrasted to the front tires in former years. This increased wear means greater polishing action. *In other words, highway engineers can look forward to even greater polishing action in the future.*

A great deal of thought is being given by automotive engineers to various approaches that might aid in safer automotive transportation. Some of those relevant to skidding (including avoidance of skid), have been cited by McConnell<sup>1</sup> as falling under three groups.

1. Automatic devices that relieve drivers of necessity for decision (sensing devices for applying brakes, guidance systems).
2. Improvement of access to information on which the driver makes his decisions (improved visibility, lighting, signaling from car to car).
3. Utilization of the superior abilities of human beings. (Use of the hand which is faster than the foot, use of audible rather than visual warning systems.)

*Summary, Vehicle*—Some improvement in the handling characteristics of vehicles can be expected but no immediate and substantial improvement is in sight for improved panic skid resistance characteristics. Also higher engine power will increase the polishing rate on highway surfaces. There is a strong possibility of improvements as cited by McConnell, depending on the reaction of the consumer to these improvements.

## BRAKES

First, it would probably be most appropriate to survey the present status of the brake. The problem of providing adequate braking for passenger cars has been less complex than for the heavier vehicles. A great deal of research has been devoted to the problems and undoubtedly will continue. The major facets of the problem have been: (1) the overcoming of brake "fade" and (2) the attainment of proper distribution of braking force on the various wheels; this latter factor is especially important on trailer and semi-trailer type trucks.

Brake fade means the loss of braking power because of the heating at the interface of two friction surfaces. Oetzel<sup>2</sup> explains that improvements in brake fade must undoubtedly take the form of improved materials from which to manu-

<sup>1</sup> McConnell, W. A., "Traction and Braking Characteristics of Vehicles", paper at First International Skid Prevention Conference.

<sup>2</sup> Oetzel, J. G., "The Fundamentals of Braking—Heat Capacity and Control", paper at First International Skid Prevention Conference.

facture brakes. He relates that although this is being given considerable attention, there is no immediate prospect of shortening stopping distances appreciably. In general, Oetzel believes that the greatest immediate benefit can come about from a more enlightened use of the existing brakes. For instance, Oetzel mentioned that the pumping of the brakes during a long braked down-hill descent (popularly considered to be beneficial) is not good practice and, in fact, contributes to higher brake temperatures and therefore increases fade.

The second major problem is that of obtaining the proper brake torque on the various wheels of a vehicle, especially trucks. Uneven brake torque can result in jackknifing of combination vehicles or spinning of passenger vehicles. An automatic device to adjust brake torque for each wheel in proportion to the load on the wheel has been suggested to prevent this but Oetzel cites the added expense and complexity from the maintenance standpoint if and when the device is developed. Here he sees also the greatest benefit in the improved technique in the use of the existing braking systems.

It would appear that the existing types of brakes have attained a position which will be difficult to improve upon. However, some new developments in a different type of brakes are appearing. Some substantial benefit might eventually accrue from the development of a non-locking brake device.

Before discussing this new development, it may be well to digress and explain a few fundamental principles about brakes and road friction. Generally speaking, there are two types of friction developed between the tire and the road as the brakes are applied. One is called impending friction and is the friction that is created when the wheel is braked but rotating, and the other, called locked-wheel friction, is the resistance that is created when the wheel is not rotating. This is important because the resistance of a rolling wheel and a locked wheel differ considerably. This is shown in Figure 1 where the changes in the  $c/f$  (and therefore retarding force) are plotted vs. time. As the brakes are applied to a passenger car the rotation of the braked wheel is slowed down but the wheel continues to rotate. Actually the wheel is rotating at a slower rate than a free wheel would be at that particular speed. The retarding force, increases rapidly to a maximum. As the brake pressure is continued the wheels lock and note that the retarding force is less when this happens. It follows that if the retarding force could be maintained at the peak level, a shorter skid would result. The well-known advice to pump brakes when the shortest possible stop is desired originated with the principle that pumping would result in the utilization of this peak value rather

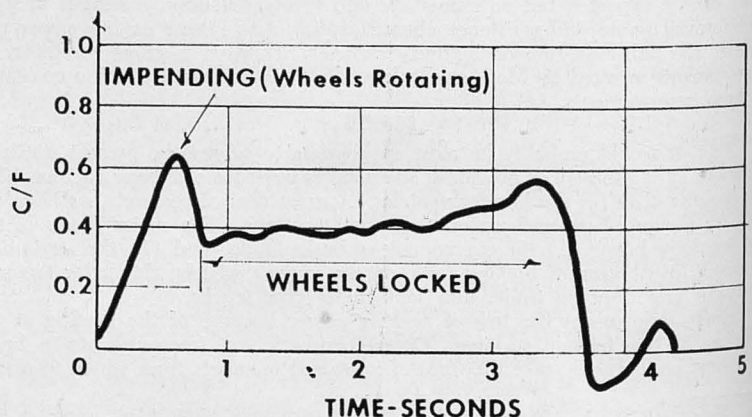


Figure 1. Retarding forces during a skid.



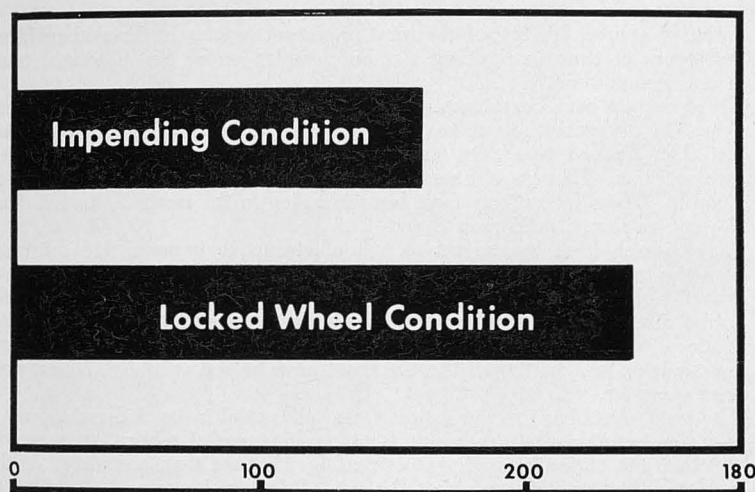


Figure 2. Benefit from impending condition.  
(Length of skid 40 mph)

than the lower locked-wheel value. However, most engineers consider the average driver incapable of using brakes effectively this way and believe that the procedure is ill advised.

Now, if a brake could be developed that would automatically maintain the maximum retarding force (the peak value on the curve in Figure 1) this would result in significantly shorter stopping distances. The improvement that could result is shown in Figure 2. The stopping distances shown have been computed from the measured coefficients of friction on a section of road in Virginia.

Such a device has been used in aircraft for a number of years. A report at the First International Skid Prevention Conference on the adaptation of one of these devices to a passenger vehicle was presented by Lister and Kemp<sup>3</sup> of the British Road Research Laboratory. Their experiments showed that some benefit will result from the use of non-locking type of brake and they anticipate that further developmental work will prove that an automatic non-locking brake will be a great benefit in preventing skidding accidents by appreciably shortening stopping distances.

Another benefit that will accrue from using non-locking brakes should be pointed out. When the wheels of a vehicle are locked the path of the vehicle is dependent only on the external forces operating on it; that is, the driver has practically no control. The turning of the steering wheel will not alter that path that the locked-wheel vehicle will take. With non-locking brakes the wheels are rotating (at maximum friction the wheels are slipping only 10-15%) and the vehicle will respond to the steering controls. This would be of tremendous benefit in the avoidance of skidding accidents on extremely slippery wet or icy roads.

**Summary, Brakes**—No immediate improvement is in view but the development of new materials and non-locking brakes is very promising and automatic torque controls a possibility.

<sup>3</sup>Lister, R. D., and R. N. Kemp, "Experiments to Prevent Wheel Locking During Braking", paper at First International Skid Prevention Conference.

## TIRES

Tires, of course, are one of the most important aspects in the skid problem. The influences of tires on skidding can be classified under two headings: tread design and composition.

Tread designs have been investigated thoroughly by the various rubber manufacturers. On dry pavements it has been found that smooth tires are more skid resistant than treaded tires. On wet and icy pavements, however, the treaded tires are superior. The use of sipes or lateral cuts also increases skid resistance considerably. These lateral cuts have been included in the tread design for about 6 or 7 years as shown in Figures 3 and 4.

An approach tried by the rubber manufacturers to improve skid resistance has been the tractionizing and adding of foreign matter to the tire tread. Several examples are shown in Figures 5 and 6 where attempts have been made to alter the texture of the tire tread. The purpose of adding corn grits (see Figure 6) was to include a material that would soon wear away and provide a rough texture. The tractionizing and gritting of the tire tread have helped only slightly and wear has been excessive.

The type of rubber used in a tire is also influential in its skid resistance. It is shown, for instance, that tires made from certain types of rubber are more skid resistant than the currently used synthetic rubber, but the demands placed on the design of tires are so numerous that the use of those rubbers most beneficial to skid resistance would greatly reduce wear resistance, and/or toughness. Almost all commercial tires in this country are made from a similar type of rubber (styrene-Butadiene) and no prospects are in the offing for any appreciable benefit from change in composition.

There is, however, a prospective improvement resulting from the theoretical work of the English physicist, Dr. Tabor<sup>5</sup> and explained by him at the Conference. His work shows that the use of tread rubber with low elasticity and a narrowing of the tread might bring substantial benefit. Laboratory experiments by the British Road Research Laboratory have shown that the principles behind the proposed design are sound. The tire manufacturers in this country and abroad are experimenting with it.

*Summary, Tires*—No immediate improvement can be expected but the theoretical work of Dr. Tabor is encouraging. However, the development and testing of his concepts will require a number of years of further work.

## HIGHWAY SURFACES

Surprising differences in frictional resistance can be found on wet roadways. I might cite an example from pavement surfaces that have been tested in Virginia. We have found stopping distances from 40 mph of from 75' to 240' on two different wet road surfaces.

The most frequently mentioned causes of low friction are: (1) bleeding of asphaltic surfaces, and (2) polishing of aggregates.

The bleeding of asphaltic surfaces is generally associated with application type of treatments and the avoidance of bleeding has been sought for a number of years. The literature on the subject is so voluminous as to not require discussion here. The significant point here is that in some states, bleeding is considered to be a major cause of slippery roads and in other areas, bleeding is not widespread, hence the problem is not serious.

The most common cause of slipperiness is the polishing of aggregates. It has been clearly established that certain types of aggregate are more susceptible to polishing under traffic than others. In general it is the limestone-dolomite group that is most susceptible to polishing. This has been found to be so in a number

<sup>4</sup> Marick, L., "The Effect of Tread Design", paper at First International Skid Prevention Conference.

<sup>5</sup> Tabor, D., "The Importance of Hysteresis Losses in the Friction of Lubricated Rubber", paper at First International Skid Prevention Conference.

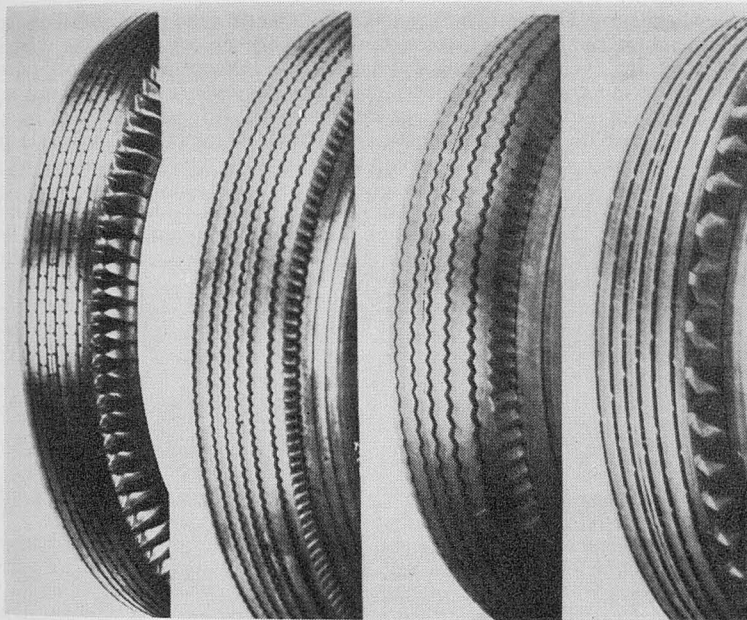


Figure 3. Typical anti-skid designs-passenger tires, 1940-45.  
(From Reference 4)

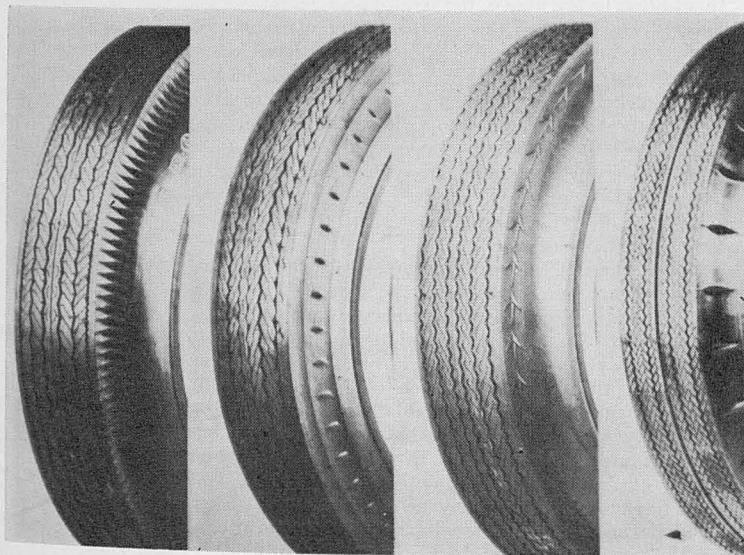


Figure 4. Typical anti-skid designs in passenger tires 1957-58.  
(From Reference 4)



of states and several foreign countries as well. Quartz aggregates and those rocks containing appreciable percentages of the quartz mineral are among the most polish resistant, but even these stones may polish. For instance, granite block surfaces in Europe have become polished after many years of use. In the opinion of many the only type of surface that will not eventually polish is one in which the wear is uneven; either the surface aggregates are abraded (rather than polished) from the pavement very slowly or the individual minerals in the aggregates exhibit differential wear.

The texture has also been shown to be important. The consensus of the experience is that the sand-paper texture is most skid resistant, other things being equal. A "knobby" texture is no assurance of high skid resistance; such textures can exhibit extremely low skid resistance.

The solutions that highway engineers have found for the slipperiness problem are varied depending on local conditions. It appears that a solution that has proved effective in one area is not necessarily successful in another. The solutions can be broadly classified as:

(1) *Deslicking treatments*—applied on roads whose only deficiency is the lack of skid resistance, and

(2) *Preventing slipperiness* by "building-in" permanent skid resistance at the time of construction.

The deslicking procedures generally involve the application of a thin surface to the slippery road. Three procedures have been used.

(1) *Application of a sandy type mixture*—either rock asphalt or a plant made hot mixture. The plant made variety has been used extensively in Virginia on portland cement concrete and asphaltic surfaces.

(2) *Seal Coats or Surface Treatments*—California and England report good success.

(3) *Resinous Treatments*—used experimentally on bridge decks. The resinous treatments are not considered to be feasible for use over any appreciable mileage of roadway. The cost of the resinous treatment is so high as to be prohibitive for all but short installations.

In addition to the above, the work of Stutzenberger and Havens<sup>6</sup> suggests that the polished condition of the aggregates on the surface could be coarsened by applying an abrading material. As far as the author knows, this approach has not been investigated extensively but is certainly worthy of additional work.

Those agencies that favor the sandy type of treatment do so because of the extremely high skid resistance it possesses, and when applied with a mechanical paver it will not bleed (which also causes slipperiness) as do some surface treatments. The aggregates used in any type of deslicking treatment, however, must be polish resistant. It is the opinion of many and the author also that aggregate types that become polished when used in one type of surface mixture will also become polished in another type.

The "building-in" of permanent high skid resistance has taken several forms. These can be grouped broadly as:

1. The total exclusion of those aggregates susceptible to polishing.
2. The addition of polish resistant materials to an aggregate that normally results in a slippery surface.

The first procedure, elimination of polish susceptible aggregates, is being followed by Virginia on the Interstate System at present and probably will extend to the primary system shortly, and the second procedure is being followed by Tennessee, Kentucky and others. In Virginia the addition of sand up to 25-30% of the total aggregate was found to be beneficial but did not consistently provide high skid resistance so the policy of eliminating polish susceptible aggregates entirely from surface courses was adopted. In general it can be stated that information on the "cures" is scant at the present time, probably because some of the high-

<sup>6</sup> Stutzenberger, W. J., and J. H. Havens, "A Study of the Polishing Characteristics of Limestone and Sandstone Aggregates in Regard to Pavement Slipperiness", HRB Bulletin 186.

way agencies have not adopted a specific approach, or are just beginning to work on the problem.

*Summary, Highway Surfaces*—There is overwhelming evidence from this country and abroad that aggregates of certain geologic classifications differ tremendously in their tendency to polish under traffic. In general, the limestone-dolomite group is most susceptible to polishing and the high silica group (quartz, granites, sandstone) the least susceptible. Also the problem must be attacked on a local level if high skid resistance is to be provided economically.

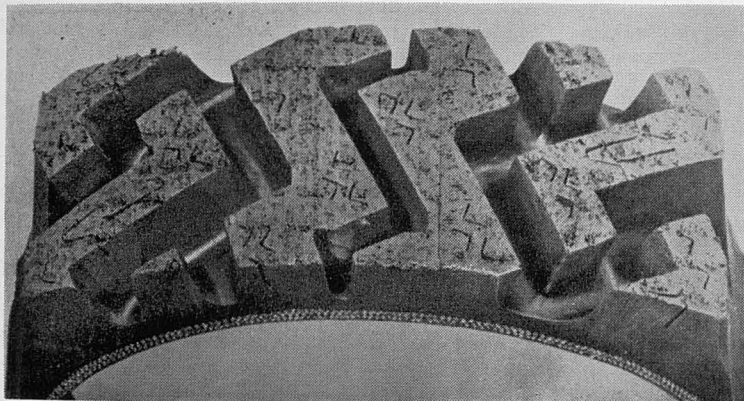


Figure 5. "Tractionized" tread treatment.  
(From Reference 4)

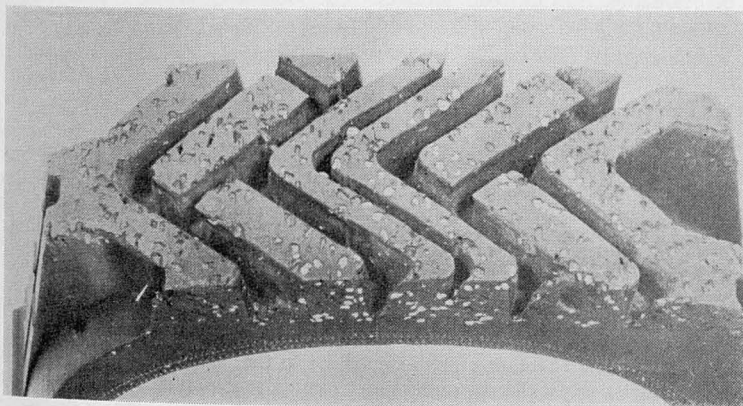


Figure 6. Tread stock with corn grits.  
(From Reference 4)

#### MEASUREMENTS

The measurement of road surface slipperiness is, of course, vital to a reduction in skidding accidents. Only by measurements can the causes of the slipperiness be determined and improvements made. There are a great many devices that are used to measure road surface slipperiness in the field. These can be broadly grouped under:



1. stopping distance methods, in which the length of a skid is measured,
2. trailer methods with which the force required to drag a trailer with the wheels locked is measured.
3. devices in which a wheel is set at an angle to the direction of travel and may be towed, "carried" in a vehicle, or an integral part of the vehicle itself,
4. portable methods.

A correlation conducted in conjunction with the Conference, including machines in categories 1, 2, and 3 has shown that the machines do not agree very well with each other. The conclusion reached as a result of this study was that the differences between stopping distance machines are apt to be less than those between the trailers. Also, as a result of the study a program of research on the problem of measurements has been outlined by a group associated with the Conference and is being actively pursued at the present time.

One specific recommendation that resulted from one of the committees of the Conference was that until a standard is developed and approved by ASTM, the skid test values be related to the stopping distance results.

In addition to field testing equipment a great need has developed for laboratory procedures to investigate the influence of various factors on slipperiness. Only in the laboratory can the necessary control be exerted to isolate the many variables. Many agencies are interested in the development of laboratory procedures. The outstanding work of Stutzenburger and Haven at Kentucky is promising as is also the work of others. It is the hope of many that eventually a laboratory test may be substantiated that will permit the evaluation of aggregates prior to their use in the field. Such a device would eliminate the need for deslicking by making possible the design of surfaces that would never get slick. Such a device would eliminate the necessity of the total condemnation of certain aggregate groups as must be done at the present time.

*Summary, Measurements*—The stopping distance method can be immediately applied (and is the only test method that can) over the entire country as a standard of evaluating existing road surfaces. The laboratory methods show considerable promise of being eventually applied as an acceptance test and a design tool, but this is probably several years away.

#### HUMAN FACTORS

In addition to the physical facets of the skidding problem—the vehicle, the tire, and the road surface—the driver certainly plays a most vital part in any overall reduction in skidding accidents. Erroneous driver responses can minimize the benefits that might accrue from engineering improvements in the vehicle-tire-road system. The areas of human engineering in which a substantial reduction in skidding accidents can be achieved could be classified under three broad headings:

1. Adaptation of the machine to the superior human capabilities.
2. Avoidance of skid inducing situations through better knowledge.
3. Development of techniques and skills to avoid accidents once an emergency situation develops.

The first item, adaptation of the machine to the superior human capabilities, has been discussed previously under improvements in vehicles. Some additional comments more strictly related to the driver are discussed here. Certainly the relationship of driver and vehicular "feed back" is an important factor in skid reduction. That is, the machine itself must give warnings to the driver of the extent to which the vehicle is under control. An example of this is the deliberate design of "feel" into the steering systems of automobiles. Power steering without this "feel" would be extremely hazardous. Forbes<sup>7</sup> suggests another type of sensory cue for the driver. He suggests the deliberate underdesigning of the super-elevation on the spiral approaches to curves so that a slight off-balance feel will

<sup>7</sup> Forbes, T. W., "Driver Knowledge, Judgment, and Response in Skidding Causation and Control", paper at First International Skid Prevention Conference.

result prior to entry into the most dangerous part of the curve. Other specific types of feed back could be elaborated here but let it suffice to say that the relationship of the driver and the vehicle is being studied and the factors influencing the relationship are being delineated.

The second phase, the avoidance of skid inducing situations, has been given considerable attention in driver training schools and through means of public information. While this training has made a great contribution to safety, there is still considerable room for improvement. Some important things that the driver should know he does not, and some of what he thinks he knows is misinformation.

The third phase, training in emergency procedures, has been seriously neglected in the opinion of many. The training to date has been relatively ineffective. Authorities informed in these fields have concluded that the driver must learn by experiencing the emergency. Knowledge of what to do is therefore not the final answer. The experience can be gained in several ways, (1) by full scale procedures wherein the techniques apply but situations are not dangerous, or (2) by driver simulators that reproduce the essential sensory conditions.

*Summary, Human Factors*—The human element in the skidding problem must be recognized as one of the most important factors in the reduction of skidding accidents. Relatively little is being done on some phases such as developing emergency driving skills but a conjecture can be made that the need for a new approach to driving training has been recognized and that the next 10 years will bring many innovations in this area.

#### DISCUSSION—ROLE OF HIGHWAY ENGINEER IN REDUCING SKIDDING ACCIDENTS

The foregoing review has shown that in the reduction of skidding accidents the highway engineer has allies in the other phases of the automobile transportation industry. There are many very real possibilities of improvement in vehicles, brakes, and tires and human engineering but these will not alleviate the immediate problems in the next five or ten years. It must be remembered that these are crucial years to the highway engineer—the years in which much of the Interstate System will be planned and built. The increase in total traffic volumes, the increase in truck freight, the increase in average speed that are certain to occur on the Interstate System all make the providing of high traction vital. It appears quite certain that the highway industry is the only one capable of making a substantial contribution in the immediate future.

In my opinion, the problem of providing high skid resistance in the immediate future must rest on the shoulders of the highway industry. This means that each state must face the problem and decide whether it is beset with slippery roads when related to existing tire, brake, and vehicular design. Some states have the good fortune not to be because of the aggregates and surface mixtures that are used. Others may be unaware of the extent to which their roads are slippery. The following steps would appear to be a reasonable approach to the problem:

1. *Recognition of Problem*—If limestone or dolomitic aggregates are being used the highway engineer should not necessarily condemn them but should be suspicious of slippery conditions, or, if the number of accidents appears to be high in a certain area or on a certain section of road, then further testing should be performed.
2. *Detection of Slippery Surfaces by Measurements*—Subcommittee E of the Conference (responsible for determining the present status of testing) has specifically recommended that the stopping distance procedure be used as a temporary standard of evaluation of pavement slipperiness. The recommendation did not propose that other existing testing methods be discarded but that the slipperiness measurements be expressed in terms of what a stopping distance device would have obtained. This was suggested so that there would be a common standard of reference throughout the country.

3. *Selecting a Minimum Acceptable Value*—At the present time no precisely derived criterion exists for determining when roads should be deslicked. The minimum wet surface standards of several European and domestic highway agencies are cited below to show that there is fair agreement as to what this minimum should be. In England the minimum  $c/f$  for tangents is 0.4; in Paris 0.5 (if the road is below 0.5 after one year the contractor must place deslicking treatment at his own expense); in Milan, Italy, if the  $c/f$  is less than 0.5 measured shortly after construction, or 0.45 after 3 years, then the contractor is held responsible for deslicking the surfaces. In this country, Virginia deslicks any road exhibiting a  $c/f$  less than 0.4 and will not permit new surfaces to be constructed that might exhibit  $c/f$  less than this minimum during their life. Other states, Mississippi for one, have used the 0.4 minimum for determining when a road needs to be deslicked.

There is, I think, in the examples cited above a fair agreement on the general magnitude of a desirable minimum value. The agreement is certainly sufficient to permit the establishment of a tentative standard until additional information is uncovered. From the above, it would appear that a  $c/f$  of 0.4 would certainly be a minimum and 0.5 highly desirable. It should be added that this 0.4 (skid distance of 133') should be referred to the stopping distance method of test and measured on a wet pavement from an initial speed of 40 mph.

4. *Selecting a Skid Resistant Mixture*—Where fine siliceous sands are economically available, the sandy type of deslicking mix as used in Virginia is worthy of investigation. If polish resistant coarse aggregate is available, and the possibility of bleeding eliminated, then seal coats or surface treatments can also be investigated. On short critical locations, intersections, bridge decks, etc., the resinous treatments might be superior.

Lastly, it would appear that the highway agencies would profit from enlisting the aid of their respective research branches in seeking to determine the causes of the slipperiness and in the design of economical surface courses that will never get slippery during their life time. The work of such research agencies, Kentucky, Tennessee, Indiana, Virginia, has borne out the benefits that can be gained in this way.